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INTRODUCTION

Ian Johnston
President, REAAA

Background

One of the major objectives of REAAA is technology transfer, getting the results of new research and investigations quickly into the hands of practitioners so that the benefits can be realised with minimum delay. This journal is one of the key ways in which we disseminate new findings. Another way is by "face to face" communication at workshops and conferences. I am delighted to have the opportunity of combining these two methods on this occasion.

Every three years or so, at the conclusion of each Presidential term, REAAA conducts a major international conference. The 10th Conference was held in Tokyo in September 2000, under the leadership of my predecessor, Dr. Sadamu Mino. A feature of each conference is the presentation of awards to the most outstanding papers. In order that these papers reach the widest possible audience we are publishing the award winning papers in this issue of the Journal.

The Katahira Awards

The awards were established in memory of the late Dr. Nobutaka Katahira, who was President of REAAA in the mid 1980s. He had a vision to promote excellence among young engineers and left a legacy of 3 million yen for this purpose. The Council has placed the focus on encouraging young professionals to develop their skills and disseminate their ideas through a set of eligibility criteria.

The current eligibility criteria are:

1. The author must be under 40 years of age at the time of the submission of the paper (when there is more than one author, only the authors under 40 are eligible).

2. The author must be a member of the REAAA or an employee of an institutional member at the time of the submission of the paper;

3. Only papers contributed to the REAAA Conference, papers published in the REAAA Journal between REAAA conferences, and papers presented at REAAA sponsored activities (workshops, seminars, etc.) between REAAA conferences are eligible; and

4. Papers must not have been published elsewhere in the same form.

The judging panel for the awards to be presented at the 10th conference comprised:

- Dr. Ian Johnston (Chairman, Technical Committee) Chairman of the Judging Panel
- Dr. Dennis Ganendra (Honorary Secretary General)
- Mr. Katsunori Miyahara (Chairman, Katahira Fund Committee)
- Mr. Yukihiko Sumiyoshi (Chairman of the Scientific Committee in the 10th Conference Executive Committee)

The Winners

Dr. Hotaka Katahira, the son of the late Dr. Nobutaka Katahira, returned to Japan from the USA, where he now resides, especially to present the awards to the winners on behalf of his late father. Dr. Hotaka's presence added great significance to the occasion.

Some 60 papers were short-listed for consideration of the awards. The technical merit, the originality of the work reported and the relevance of the paper to the countries in the region served by REAAA were the three criteria applied by the judging panel.

The judging panel was unable to select a single winner so two outstanding papers were chosen. The first was a paper to the 10th Conference. Mr. Nobumasa Suzuki of Japan received an award for his paper entitled "Seismic Performance of Prestressed Concrete Piers". The second was a paper published in this Journal between the 9th and 10th Conferences. Professor Radin Umar RS of Malaysia received an award for his paper entitled "A Study on the Use of Oil Palm Fibre in Rubberised Stone Mastic Asphalt". Both authors received a certificate and a cheque of US$1,000.

In view of the numerous excellent papers received, the judging panel decided to present a further two "highly commended" awards of US$500 each to two other authors. The first highly commended paper was authored by Dr. Weederaj Cheewapattananuwong of Thailand entitled "Bus Safety in Thailand". The second award went to Mr. Kazuoyoshi Nishikawa of Japan for his paper entitled "Development of a Precast Concrete Lining Technique Using Prestressed Concrete Structures".

The four papers are presented in this Journal.

SEISMIC PERFORMANCE OF PRESTRESSED CONCRETE PIERS

Takuya Mori
Chief Engineer, P.S.Corporation

Nobumasa Suzuki
Engineer, P.S.Corporation

Shoji Ikeda
Professor, Yokohama National University

Takuya Mori is a registered consulting engineer and working for P.S.Corporation as a chief engineer of the civil engineering department at Tokyo head office. His special field is the design and research of prestressed concrete structures, especially bridges. He was a member of the *Working Committee on the seismic performance of prestressed concrete piers* in the Japan Prestressed Concrete Engineering Association. He was engaged in the Working Committee for two and half years and contributed the completion of "*Guideline on the seismic design for prestressed concrete piers* ", which was issued by, in November of the year 1999 .

Nobumasa Suzuki is working for P.S.Corporation in the civil engineering department at Tokyo head office. In the study of this paper on the seismic performance of prestressed concrete piers, he was belonging to the working group, conducted reversed cyclic loading tests and studied about nonlinear hysteresis model for PC piers.

Shoji Ikeda is professor of civil engineering at Yokohama National University and chairman of the *Committee on the seismic performance of prestressed concrete piers* which was established in 1998 in the Japan Prestressed Concrete Engineering Association.
He has been contributing to the development of concrete and prestressed concrete structures. Currently he is vice-president of Japan Concrete Institute. He was president of the Japan Prestressed Concrete Engineering Association and now a member of board of directors of the Association. He has been very active in the international field such as the senior vice president of the FIP (Federation Internationale de la Precontrainte) until 1998. And now he is a member of the Presidium of the *fib* (*Federation Internationale du Beton*).

1. Introduction

The Kobe Earthquake of 1995 (Hyogoken-Nanbu Earthquake) caused extensive damages in reinforced concrete piers designed according to traditional seismic codes. Through such a severe near field earthquake, it has become necessary to recognize that a pier must have the sufficient ductility, flexural and shear capacities. Also a pier is required relatively small residual displacement in order to keep the serviceability after the earthquake. Introducing prestress into flexural members has some definite advantages, such as greatly increasing serviceability and restoration capability. Therefore excellent seismic performance could be obtained by introducing the prestress into a concrete pier in such a way that serviceability must not be decreased and that residual displacement must be kept small after the earthquake.

In order to investigate the utilization of vertical prestressing in bridge piers, a systematic research has been carried out in Japan Prestressed Concrete Engineering Association (JPCEA). Twenty-two single column type specimens were made for the experiments of reversed cyclic loading and six specimens for pseudo dynamic test. The reversed cyclic loading tests showed that reinforced concrete columns with appropriate prestress have enough ductility and remarkably decrease the residual displacement. The pseudo dynamic tests showed that they have superior seismic performance against the near field earthquake such as the Kobe Earthquake.

This paper describes the results of the experiments and the evaluation of seismic performance achieved by introducing prestress into a concrete column, and proposes the nonlinear hysteresis model for prestressed concrete piers.

2. Outline of specimens and experiments

2.1 Test specimens

Twenty-two single column-footing type specimens were used for reversed cyclic loading tests and six specimens were used for pseudo dynamic tests. The specifications of the specimens are shown in Table 1 and the typical reinforcing bar and prestressing tendon layouts are shown in Figure 1. And the mechanical properties of the steels are shown in Table 2. The specimens were 40cm square in cross section and the loading span was 1.5m from the top of footing. The following factors are selected as experimental variables: (1) cross section shape (solid or hollow), (2) axial stress due to topside load (1 or 4MPa), (3) concrete strength (35 or 60 MPa), (4) level of prestress (0, 2, 4 or 8MPa), (5) bonded or unbonded prestressing tendon and (6) precast segmental column.

S-1, S-7, S-12 and S-15 were reinforced concrete specimens (hereinafter called RC specimens). The others were prestressed concrete specimens (hereinafter called PC specimens).

The vertical re-bars were basically arranged for RC specimens to satisfy the required bending strength. For PC specimens some of re-bars were replaced with prestressing tendons in accordance with the required

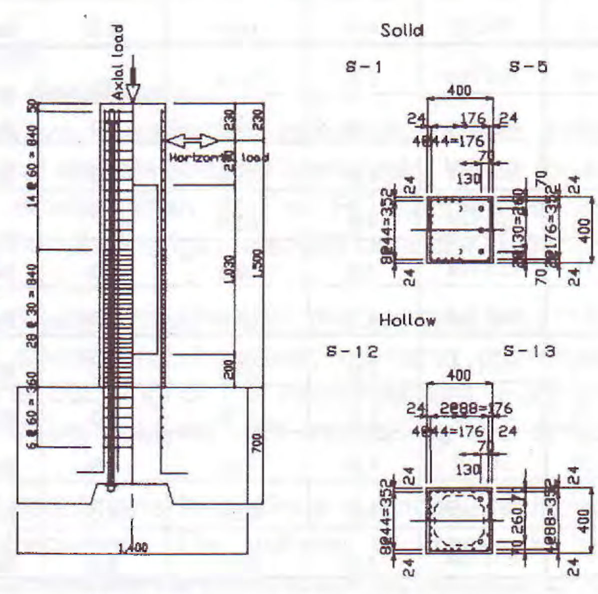


Figure 1: Detail of specimen

prestress level.

Furthermore, all of the specimens were designed to make the bending shear strength ratio (shear strength/bending strength) to exceed 1.0 to ensure the flexural failure.

The prestressing tendon is tensioned up to 50 percent of the yield strength. The maximum aggregate size used for the concrete was 8.5 mm.

Table 2: Properties of re-bar and prestressing tendon

Steel type		Yield strength (MPa)	Tensile strength (MPa)	Young's modulus (MPa)
Reinforcing bar	D6(SD345)	387	566	2.06×10^5
	D10(SD345)	401	565	
	D13(SD345)	391	567	
Prestressing tendon	SWPR7B12.7	1753	1935	1.91×10^5
	SWPR19-17.8	1790	1967	1.90×10^5

Table 1: Specifications of specimens

Specimen No.	Cross Section	Axial Stress (MPa)	Concrete compressive strength (MPa)	Prestress (MPa)	Bond Condition	Prestressing tendons	Axial reinforcing bars	Notes
S-1	Solid	1.0	35.0	–	–	–	32×D13	
S-2	Solid	1.0	35.0	2.0	Bonded	4×SWPR7Bφ12.7	16×D13	
S-3	Solid	1.0	35.0	4.0	Bonded	8×SWPR7Bφ12.7	16×D10	
S-4	Solid	1.0	35.0	4.0	Unbonded	8×SWPR7Bφ12.7	16×D10	
S-5	Solid	1.0	35.0	8.0	Bonded	8×SWPR19φ17.8	8×D10	
S-6	Solid	1.0	60.0	8.0	Bonded	8×SWPR19φ17.8	8×D10	
S-7	Solid	4.0	35.0	–	–	–	32×D13	
S-8	Solid	4.0	35.0	4.0	Bonded	8×SWPR7Bφ12.7	16×D10	
S-9	Solid	4.0	35.0	4.0	Unbonded	8×SWPR7Bφ12.7	16×D10	
S-10	Solid	4.0	60.0	4.0	Bonded	8×SWPR7Bφ12.7	16×D10	
S-11	Solid	4.0	60.0	8.0	Bonded	8×SWPR19φ17.8	8×D10	
S-12	Hollow	1.0	35.0	–	–	–	32×D13	
S-13	Hollow	1.0	35.0	4.0	Bonded	4×SWPR7Bφ12.7	16×D10	
S-14	Hollow	1.0	35.0	8.0	Bonded	4×SWPR19φ17.8	8×D10	
S-15	Hollow	4.0	60.0	–	–	–	32×D13	
S-16	Hollow	4.0	60.0	4.0	Bonded	4×SWPR7Bφ12.7	16×D10	
S-17	Hollow	4.0	60.0	8.0	Bonded	4×SWPR19φ17.8	8×D10	
S-18	Solid	1.0	35.0	4.0	Bonded	8×SWPR7Bφ12.7	–	Precast
S-19	Solid	1.0	35.0	8.0	Bonded	8×SWPR19φ17.8	–	Precast
S-20	Solid	1.0	35.0	4.0	Bonded	8×SWPR7Bφ12.7	16×D10	*
S-21	Hollow	4.0	60.0	8.0	Bonded	4×SWPR19φ17.8	8×D10	
S-22	Hollow	4.0	60.0	8.0	Bonded	4×SWPR19φ17.8	8×D10	

* Prestressing tendons are anchored at the middle height of the column.

2.2 Reversed cyclic loading tests

The loading apparatus is shown in Figure 2. In the vertical direction, the constant axial force was applied to each specimen by using hydraulic jack. The lateral reversed cyclic load was applied by the push-pull type hydraulic jack. The loading level was controlled by the rotation angle (horizontal displacement/loading span) of the loaded specimens. The ultimate state is defined as when the applied load becomes 80% of the maximum load.

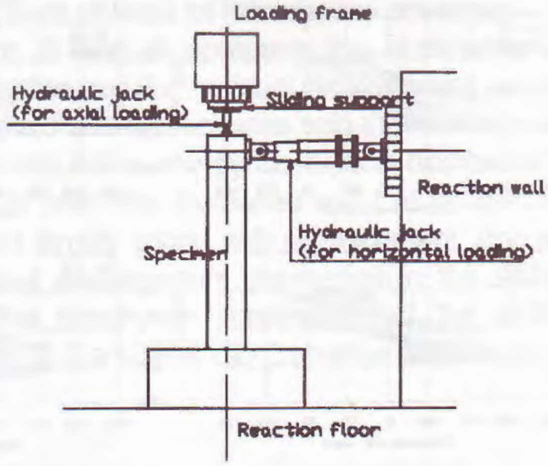


Figure 2: Loading apparatus

2.3 Pseudo-dynamic tests

To study the seismic response performance of the PC columns during an earthquake, pseudo-dynamic tests were performed under that condition which is shown in Table 3. The seismic motion employed in the tests was the record of Kobe Maritime Meteorological Observatory (Kobe MMO). The input maximum acceleration was determined from the employed virtual mass and the flexural capacity of specimens based on the following assumption. The natural frequency of these specimens was 0.3 sec, and they were designed against the equivalent horizontal seismic coefficient 0.8 in accordance with the design method of the Highway Bridge Specification, 1996.

Table 3: Specimens and test conditions for pseud-dynamic test

Specimen No.	Natural period (sec)	Initial stiffness (kN/cm)	virtual mass (t)	damping h	Input maximum acceleration
S-1	0.3	166.0	37.8	0.03	563
S-4		161.0	36.7		474
S-12		255.7	60.5		355
S-13		443.2	101.0		166
S-15		406.0	92.5		235
S-17		290.2	66.1		322

3. Results of reversed cyclic loading tests

3.1 Hysteresis characteristics and failure conditions

Figure 3 shows the load-displacement curve (hereinafter called hysteresis curve) of specimens. The RC specimens have a typical spindle-shaped hysteresis. While for the PC specimens, the residual displacement is smaller than that of RC specimens and the hysteresis during unloading tends to strengthen their origin-oriented behavior depending on the applied prestress level.

For the RC specimens, the applied load decreased rapidly after the buckling was occurred in the vertical reinforcement. For the PC specimens, however, no rapid decrease was observed in the applied load even after the buckling of the reinforcement. Furthermore, yield of the prestressing tendon tended to be delayed with increasing the amount of prestressing tendon.

Figure 4 shows the damage conditions of specimens for various quantities of introduced prestress at buckling of the vertical reinforcement. The number of cracks in the PC specimens was smaller than RC specimens and the range of crack occurrence tended to become smaller. The number of the shear cracks also became smaller.

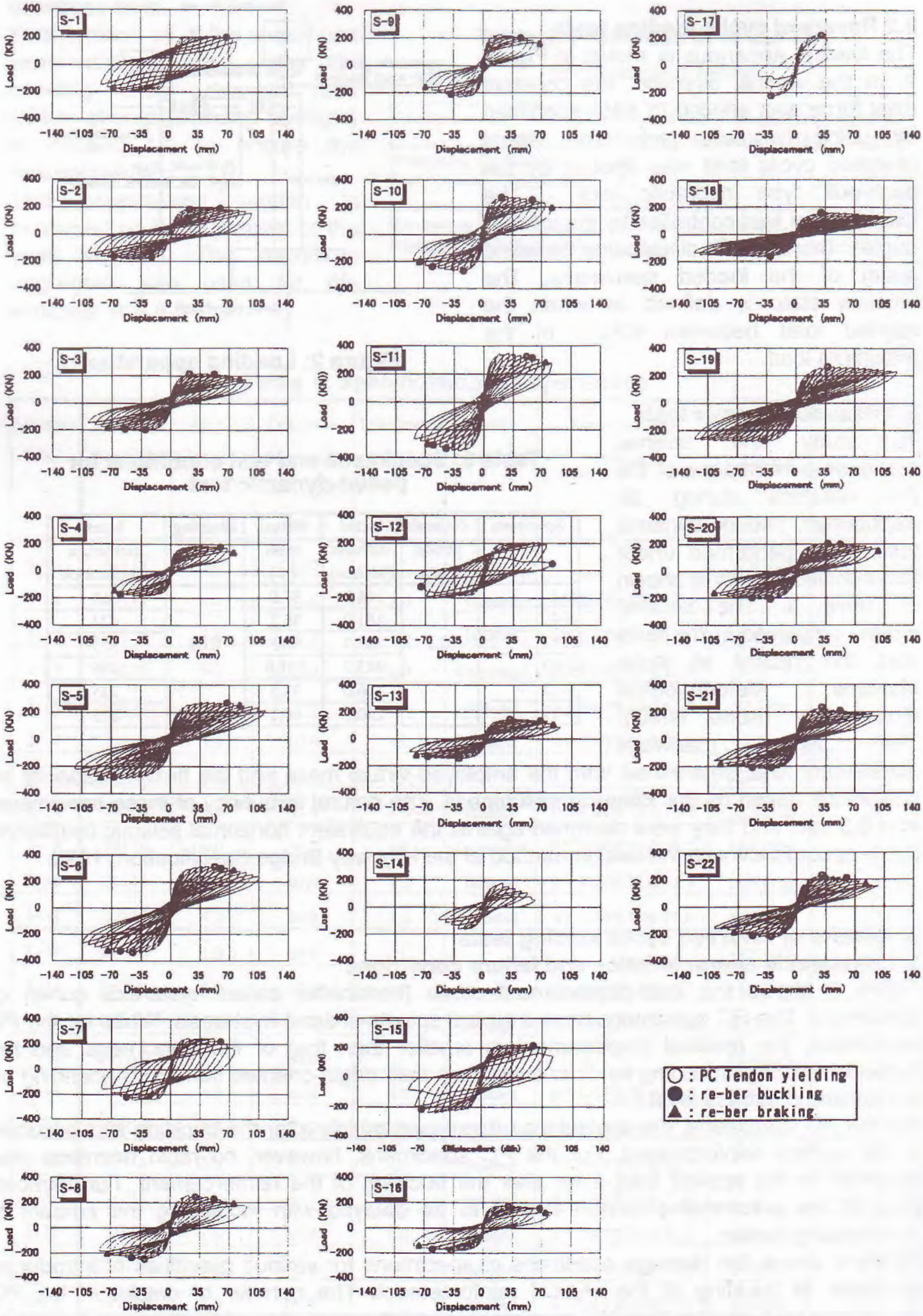


Figure 3: Experimental result of load-displacement

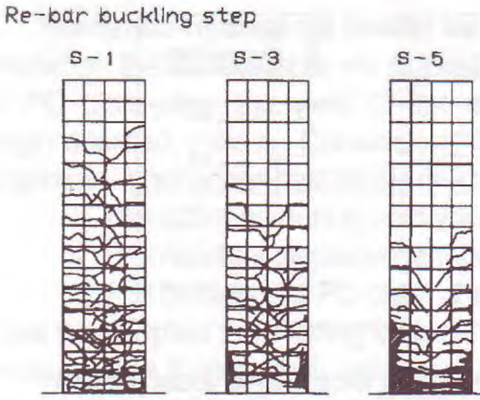


Figure 4: Damage Conditions at re-bar buckling

3.2 Effect of level of introduced prestress

Figure 5 and 6 compare the cumulative energy absorption and the residual displacement respectively of the individual specimens with the level of prestress. The cumulative energy absorption decreased as the level of prestress increased and this decreasing ratio did not largely varied with displacement. And also the residual displacement decreased in the same way, but the specimens prestressed of the 4MPa and 8MPa (S-3 and S-5) didn't change very much.

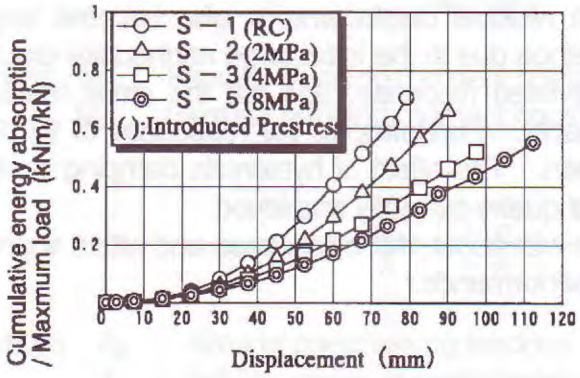


Figure 5: Cumulative energy absorption

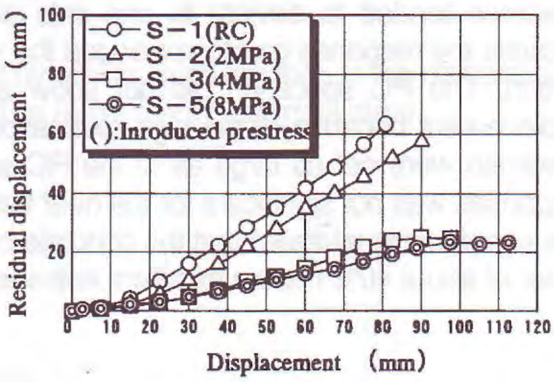
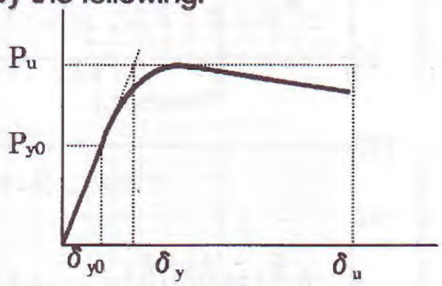


Figure 6: Residual displacement

Figure 7 shows the ductility factors of the specimens. Here, the ductility factor μ is the ratio of the ultimate displacement to the yield displacement, as given by the following.

$$\mu = \delta_u / \delta_y$$



where δ_u : Ultimate displacement (when the applied load decreased to the 80% of the maximum load)

δ_y : Yield displacement ($= P_u * \delta_{y0}/P_{y0}$)

P_u: Maximum load in the experiment

P_{y0}: Calculated initial yield load

δ_{y0}: Displacement when giving P_{y0}

The ductility factor was about 6 or 7 for RC specimens, but it was improved as the introduced prestress was increased.

Therefore, the deformation capacity is improved as the level of prestress. On the other hand increase of the axial stress by the external axial force made the ductility factor reduced shown Figure 8. By these results we

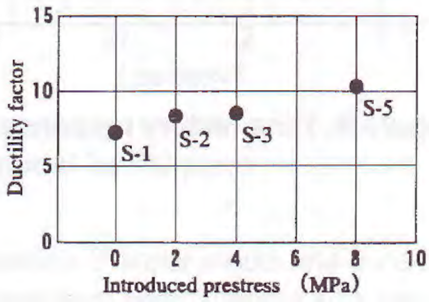


Figure 7: Ductility factor and Introduced prestress

found that the effect of prestressing is different from the external axial force for the deformation capacity, though both introduce compressive stress to the concrete.

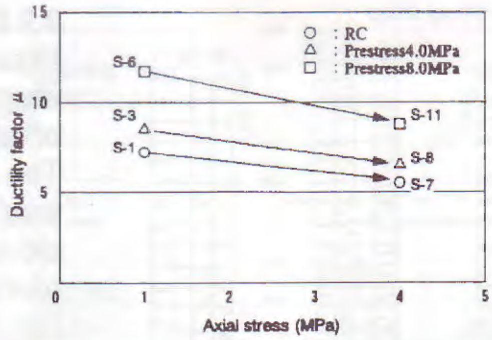


Figure 8: Ductility factor and axial stress

4. Results of pseudo-dynamic tests

The displacement time history and the hysteresis curve are shown in Figure 10 and 11, respectively for a RC specimen (S-12) and a PC specimen (S-13). The response of the RC specimen tended to deviate to one side and the residual displacements also became large, because the response greatly exceeded the yield range due to the initial large earthquake ground motion. The PC specimen did not show any deviated response, and left the small residual displacement because of the high restoration capacity. Furthermore, the responses of the PC specimen were not as large as of the RC specimen. The effect of hysteresis damping on the responses was not significant for the near field earthquake currently employed.

The experiments revealed that the concrete column with about 4MPa prestress and with a sharing factor of about 40% has an excellent anti-seismic performance.

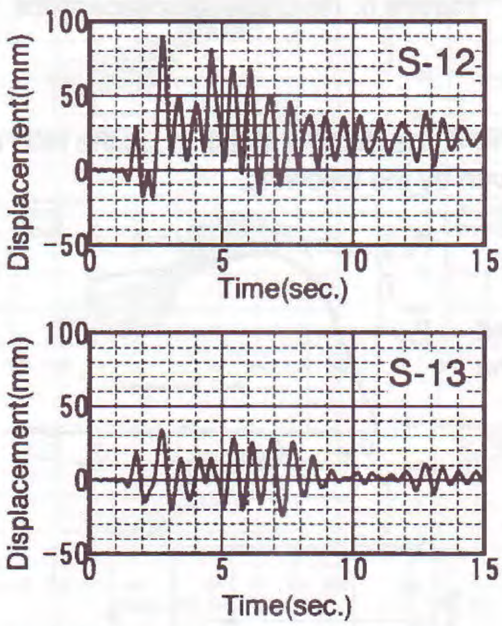


Figure 9: Time history response

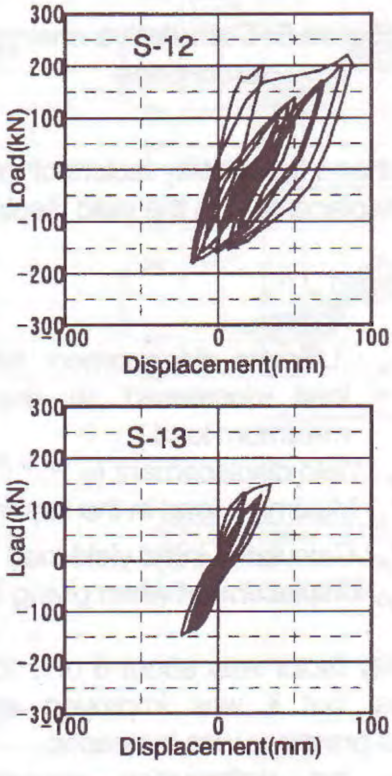


Figure 10: Load-displacement curve

5. Nonlinear hysteresis model for PC piers

Based on the experiments we studied the nonlinear hysteresis model for PC piers. The behavior of PC piers after the yield of the member is between the model for RC members and the origin-oriented model. Considering the characteristic of PC piers behavior as follows we proposed a nonlinear hysteresis model shown in Figure 11.

- The stiffness during unloading is not constant but changes halfway.
- The residual displacement becomes smaller than RC.
- The behavior of PC piers changes depending on the level of prestressed concrete.

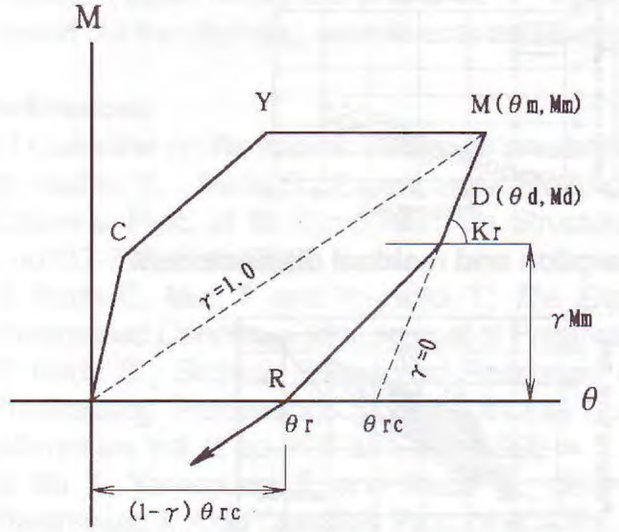
Here we adopted the sharing factor of prestressing tendon γ as the level of prestressed concrete, because that it has much relation to the behavior. The sharing factor of prestressing tendon γ means the contribution of the PC tendons to the ultimate flexural strength, is defined by the equation (1). γ can be calculated approximately by the equation (2).

$$\gamma = \frac{M_{pu}}{M_{pu} + M_{su}} \qquad (1)$$

where M_{pu} : Flexural bending moment contributed by prestressing tendons in the ultimate state
M_{su} : Flexural bending moment contributed by re-bars in the ultimate state

$$\gamma = \frac{A_p f_{py}}{A_s f_{sy} + A_p f_{py}} \qquad (2)$$

where A_p : Area of prestressing tendons
f_{py} : Yielding stress of prestressing tendons
A_s : Area of reinforcing bars
f_{sy} : Yielding stress of re-bars



$Md = \gamma Mm \quad (0 \leqq \gamma \leqq 1.0)$

$\theta r = (1-\gamma)\theta rc$

(when $\gamma \geqq 0.8$: $\gamma = 0.8$)

$\theta rc = \theta m - Mm/Kr$

Figure 11: Nonlinear hysteresis model for PC piers

The hysteresis model shown in Figure 11 is based on Takeda's tri-linear model and considered the change of unloading stiffness. When γ=0, i.e. RC, it coincides with Takeda's tri-linear model, and in the case of γ=1.0, i.e. absolute PC, it becomes origin-oriented model. And in the region of $0<\gamma>1.0$ the behavior is determined by the sharing factor of prestressing tendon γ.

Figure 12 compares the results of experiments and the proposed hysteresis model, and Figure 13 compares the cumulative energy absorption and the residual displacement. Proposed hysteresis model has sufficient accuracy.
We verified the proposed hysteresis model also to the pseudo-dynamics tests. Figure 14 shows the hysteresis curve of the experiments and the analysis using the proposed model. The maximum and the residual displacements by the analysis agreed nearly with the experiments.

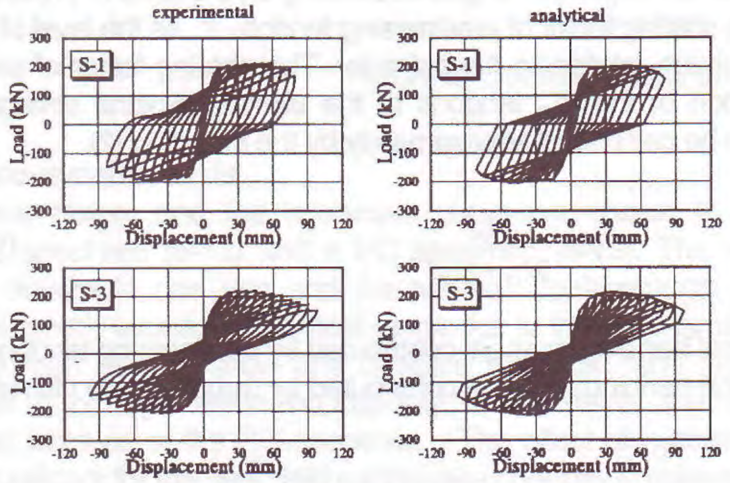


Figure 12: Hysteresis curve

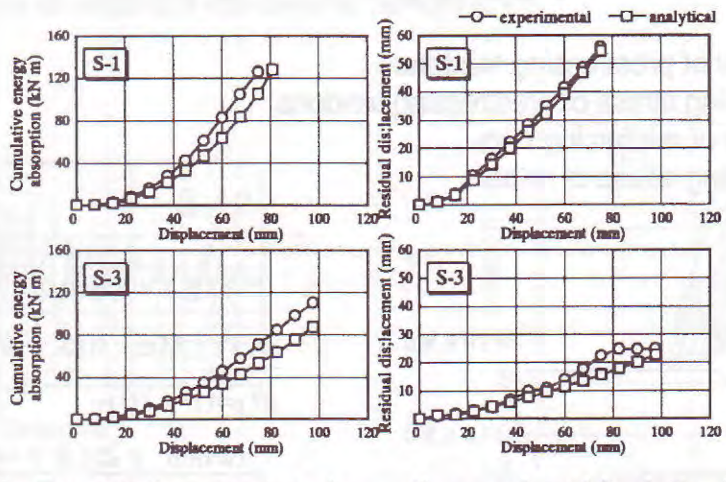


Figure 13: Cumulative energy absorption and residual displacement

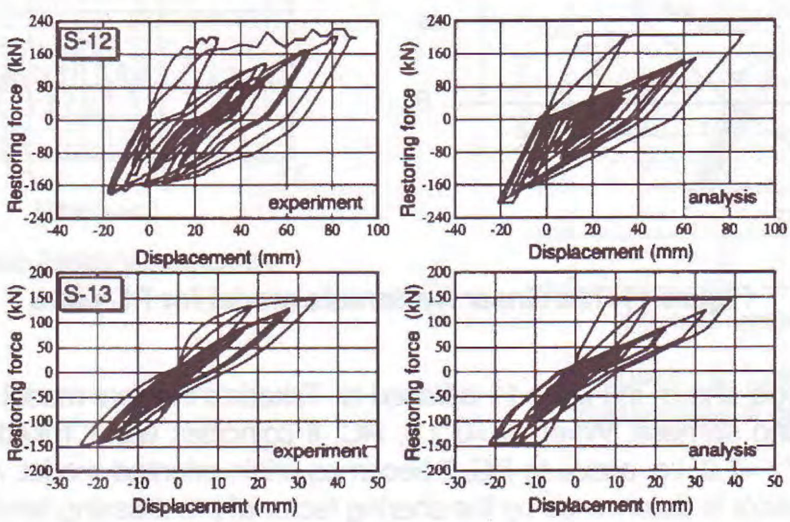


Figure 14: Verification to the pseudo-dynamics test

6. Conclusions

Reversed cyclic loading tests and pseudo-dynamic tests were conducted to investigate the basic earthquake resistant performance of prestressed concrete bridge piers. And the nonlinear hysteresis model was proposed based on the experiments. The following conclusions were drawn.

1) The applied load to the PC specimens did not drop significantly even after the vertical reinforcement buckling, but they showed ductile behavior. While the applied load to the RC specimens dropped rapidly after the vertical reinforcement buckling.

2) The PC specimens had smaller number of bending and shear cracks than the RC specimens.

3) As the level of the introduced prestress, the energy absorption decreased. However, the higher sharing factor of prestressing tendon made the residual displacement smaller.

4) According to the results of the pseudo-dynamic tests, the response of the RC specimens tended to deviate to one side in the case of the near field earthquake and the residual displacement became larger. However, the response of the PC specimens did not deviate and showed a much smaller residual displacement response than that for the RC specimens because of their high restoration capability. It is considered that the effect of hysteresis damping is small on the response.

5) The proposed nonlinear hysteresis model was proved to have sufficient accuracy to the experiments.

As described above, PC bridge columns are expected to have superior seismic performance than conventional RC columns. It is considered that practical new bridge piers can be achieved by utilizing such performance. And the proposed hysteresis model can be used for the seismic design work.

Acknowledgement

This research work has been conducted under "Research Committee for Prestreseed Concrete Piers " in JPCEA. The authors are grateful to the co-researchers, Mr. Y. Hishiki (Kajima Corporation), Mr. Y. Ishii (Sumitomo Construction Co., Ltd.), Mr. Y. Ota (Fuji P.S. Corporation), Mr. T. Shimizu (Taisei Corporation), and Dr. T. Yoshioka (Oriental Construction Co., Ltd.), who jointly carried out the planning, experiments and analyses.

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A STUDY ON THE USE OF OIL PALM FIBRE IN RUBBERIZED STONE MASTIC ASPHALT

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Abstract

Malaysia is a leading producer of oil palm in the world. As such, oil palm fiber is abundantly available in Malaysia. Although the oil palm fiber is used in several different areas a new usage of this material in Stone Mastic Asphalt mixes is worth investigating. This is because of the additional 20% cost to the mix using the traditional German Viatop66 fiber in the original specification of the SMA mix. This paper looks into the performance of SMA samples with oil palm fiber in comparison to SMA with the Viatop66.

1 Introduction

Most of the roads in Malaysia are paved with bitumen. Under the accelerated traffic growth and intense heat our pavements are subjected to drastic changes in their properties especially when heated in the presence of water and oxygen. When asphalt gets heated up, there is a tendency for the binder to soften and drain down slowly (1). A repetition of this process, may cause premature pavement distresses due to the accelerated loss of asphalt. The loss of asphalt is even higher in gap graded mixes like Stone Mastic Asphalt (SMA). One of the main reason for the addition of the fibers in SMA is to prevent the draining of the binder from the mix into the truck during transport of the material from the mixing plant to the construction site. The fibers also improve the service properties of the SMA mixes by forming a micromesh netting (2) in the asphalt mix to prevent drain-down of asphalt so as to increase the stability and durability of the pavement mix.

There are special fibers like Viatop66 fibers (3) which have been used in Stone Mastic Asphalt (SMA), for the last two decades. However, this product is currently been imported from Germany, which increases the cost of SMA in Malaysia by about 20%. In an effort to find an alternative but cost effective solution, oil palm fibers seems to offer an alternative additive for SMA fiber research. This is because oil palm fiber is found in abundance in Malaysia and the use of oil palm fiber in SMA can be inexpensive and may help reduce oil palm fiber waste in the country.

The main objective of this study is to analyse the performance of asphalt coated oil palm fiber in rubberized stone mastic asphalt. Several tests were conducted to determine the characteristics of oil palm fiber prior to use in stone mastic asphalt. This is to make sure that the organic contents in the oil palm fiber do not pose a problem in terms of durability of the mix.

2 Methodology

In this study, several experiments were conducted to determine the characteristics of oil palm and the control Arbocel Viatop66 fibers, in the rubberized binder. This was done to ensure that all the materials used fulfil the basic specifications and requirements of SMA (3). Samples were made with different sizes of oil palm fiber which approximately resemble the size of the imported Viatop66 fiber. The SMA with Viatop66 fiber was treated as the control sample.

Preliminary tests were carried out on the different types of raw oil palm fibers to determine their physical properties. The tests involved the analysis of fiber size, moisture content and specific gravity. For the long type fibers the tensile strength of the fiber was tested using the INSTRON Machine. Four sizes of oil palm fiber were selected and tested. The meshed fiber sizes of 106µm, 180µm, 250µm and 300µm were tested for the comparison study.

In addition to the above tests, the Resilient Modulus, Fatigue and Dynamic Creep tests were also conducted on the SMA mix with oil palm fiber and the control SMA with Arbocel Viatop66 fiber. The determination of the optimum content oil palm fiber was done by the Marshall analysis and resilient modulus methods. The optimums were selected on basis of maximum stability, maximum bulk density, maximum resilient modulus and 4% airvoids.

The percentage of asphalt used was 6% by weight of total mix and the percentage of rubber in the asphalt-rubber blend was 4% by weight of asphalt. The meshed oil palm fibers and the Viatop66 fibers were tested for drain down properties using the German in-house 15W 40 motor oil-fiber test. The fibers were stirred at 1000 rpm in 160ºC oil and is placed on a 500µm-sieve. After 5 minutes the mass of oil running through the sieve is measured.

Binder drain down tests were also carried out on the SMA samples with and without the fibers, to determine their binder retaining properties. The samples were prepared in accordance with Schellenberg's procedure (4). The aggregate gradation for SMA was based on the previous study carried in UPM (5).

3 Results

3.1 Physical Properties of Unmeshed Oil Palm Fiber

The tests show that the average tensile strength of the long type fiber strands is quite good (Table 1). This was used as the basis to select the type of oil palm fiber for meshing and grinding. From the above process four sizes were obtained. They are 106µm, 180µm, 250µm and 300µm. It was not possible to carry out tensile strength test on the short type fiber and fiber dust.

Table 1: Physical Properties of Unmeshed Oil Palm Fibers

Fiber Category	Category	Length (mm)	Width (µm)	Moisture Content (%)		Specific Weight (kg/m³)	Tensile Strength (kPa)
				Air Dried	Saturated		
Dust	Minimum	3.0	27.77	13.4	32.5	–	–
Dust	Average	7.1	34.07	14.9	35.3	13.28	–
Dust	Maximum	13.0	38.89	16.9	36.9	–	–
Short	Minimum	7.0	127.78	12.9	40.1	–	–
Short	Average	17.4	151.48	13.3	42.0	8.74	–
Short	Maximum	28.0	161.11	13.6	44.2	–	–
Long	Minimum	20.0	105.58	5.7	61.5	–	–
Long	Average	142.3	358.34	7.0	63.2	7.73	5.67
Long	Maximum	315.0	777.77	7.7	65.2	–	–

3.2 Oil Drain-down Properties of Meshed Fibers

Table 2 below shows the results of the oil retaining properties of the oil palm fiber against the imported Viatop66 fiber. The weight of oil drained out of the Viatop66 fibers is about 151.0g while the oil drain-down value for the oil palm fiber is about 105.0g. The max allowable value for any suitable fibers is 180.0g.

Table 2: Oil Retaining Properties of Fibers

Specimen	Viatop66	Oil Palm Fiber
Weight of pan (g)	293.5	293.5
Weight of pan + Drained motor oil (g)	444.5	398.5
Weight of MotorOil (g)	151.0	105.0

3.3 Results of Optimum Oil Palm Fiber Content

The resilient modulus test results at 25ºC for 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% oil palm fiber content for each sizes are shown in Figure 1. The resilient modulus of SMA mix at 25ºC increased with an increase in percentage of oil palm fiber up to an optimum and then decreased. All of the fibers including the Viatop66 (control) displayed a similar increasing and decreasing trend. From the curvers obtained, it can be seen that SMA samples with the oil palm fiber size of 300µm gave the highest resilient modulus value and comparable with the control mix using

Viatop66. The fiber content of about 0.6% gave the optimum modulus of about 3500MPa. The fiber size of 180μm however displayed the lowest value.

3.4 Binder Draindown

Binder drain down analysis was carried on SMA with Viatop66, SMA with oil palm fiber and SMA plain. Table 3 shows the results of the binder drain down tests. It was found that the mix with oil palm fiber showed a lower value compared to the mix without any fiber and the mix with the Viatop66 fiber. The maximum permissible value is 0.3 percent.

Table 3: Binder Drain Down Properties of SMA

Mix Type	Sample No.	Wt. of Sample	Wt. Retained	% Retained	Ave. %
SMA-VT66	1	1016.4	1.20	0.1181	
	2	1018.1	1.21	0.1188	
	3	1017.0	1.20	0.1180	0.12
SMA-OPF	1	1019.0	1.00	0.0981	
	2	1018.6	0.90	0.0884	
	3	1016.9	1.10	0.1082	0.10
SMA-Plain	1	1019.5	4.59	0.4502	
	2	1017.1	2.54	0.2497	
	3	1019.7	3.57	0.3501	0.35

(note: binder content is 6.0%: VT66 = Viatop66: OPF = Oil Palm Fiber)

3.5 Marshall Stability

The Marshall Stability (Table 4) of the test samples and the respective graphs are shown in Figure 2. It can be seen that Marshall stability values increased when the percentage of oil palm fiber was increased. The highest stability values were obtained for 250μm fiber size with 16.31kN. A comparable result was obtained for the 300 micron fiber at 0.6% fiber content with stability about 12.37kN. However the stability values of each fiber content do not vary much between the four different sizes of oil palm fiber.

3.6 Marshall Density – Airvoids Analysis

Figure 3 to 5 show the Marshall bulk density, voids in the mix, flow and the voids filled with Asphalt values. From the plots it can be seen that both the oil palm and Viatop66 fibers displayed similar trends. The oil palm fibers in particular showed values which are close to or even better than Viatop66 fibers. Table 5 shows the bulk densities for the optimum fiber contents of each fiber size.

Table 4: Stability Results for Optimum Oil Palm Fiber Content

% OPT FIBER	STABILITY (KN)				
	106μm	180μm	250μm	300μm	Control
0.2	10.97	6.21	10.85	7.58	15.51
0.4	10.15	8.04	16.31	10.03	16.61
0.6	10.38	8.45	10.72	12.37	16.28
0.8	12.72	7.47	13.37	11.43	15.72
1	9.8	6.88	11.29	10.72	15

Table 5: Bulk Density of Each Oil Palm Fiber Size and Content

% FIBER	BULK DENSITY				
	106μm	180μm	250μm	300μm	Control
0.2	2.28	2.31	2.31	2.25	2.274
0.4	2.29	2.32	2.3	2.29	2.32
0.6	2.29	2.23	2.34	2.29	2.35
0.8	2.31	2.33	2.32	2.32	2.28
1	2.24	2.29	2.33	2.26	2.26

3.7 Dynamic Creep Performance

Dynamic creep test was carried out on SMA samples with Viatop66 and oil palm fibers. A set of SMA samples without fibers were also tested for comparison purpose. Table 6 shows the results of the different SMA mixes. SMA with the Viatop66 fiber gave the highest values in terms of the number of load cycles to reach both the 1% and 3% strain levels. However SMA with the oil palm fiber displayed equally good results.

Table 6: Dynamic Creep Results of SMA

Mix Type	1% Strain	3% Strain
SMA Plain	153	3906
SMA-VT66	454	7461
SMA-OPF	404	5400

4 Discussion and Conclusion

From the results obtained, it can be seen that the oil and binder retaining properties of the oil palm fiber are superior to the traditional Viatop66 fiber. The oil retaining value of the oil palm fiber (105.0g) is far below the max allowable maximum weight of 180.0g compared to 151.0g for the Viatop66 fiber. The binder draindown value of the SMA mix with oil palm fiber is very much lower than the permissible 0.3%. Both the oil and binder retaining values of the SMA mix with the oil palm fiber are more than acceptable. The results thus indicate that oil palm fiber may be used as a direct substitute for the more expensive cellulose-based fiber, currently used worldwide.

Table 7 shows the summary of SMA mix requirement (3) and the Marshall results of SMA with oil palm fiber (300 micron). Overall, SMA with oil palm fiber showed results which are within the SMA requirement range, except the flow which is a little lower than the required minimum.

Table 7: Comparison Between SMA with 0.6% Oil Fiber and SMA Control

Marshall Design Parameter	SMA-Oil Palm Fiber (size 300μm)	SMA Control (Viatop66 Fiber)	Acceptance Limits
Voids In Total Mix, VTM	4.64%	4.50%	3% – 5%
Asphalt Content, percent	6.0	6.10	6.0 min.
Voids In Mineral Aggregates, VMA	18.0	17	17% min.
Stability, N	12.37kN	16.28kN	6.2kN (min.)
Flow, 0.25mm (0.01 inch)	4.7	5.75	6 – 8
Compaction, number of blows at each side of test specimen	50	50	50

The 300 micron fiber seems to be quite consistent in terms of the overall performance (Table 8). It is obvious that the oil palm fiber performance in terms of stability, resilient modulus and bulk density is very much comparable to the Viatop66 fiber. For each oil palm size the optimum fiber content range was determined based on the maximum bulk density, stability and resilient modulus. The average fiber content ranges are shown in Table 9. For the chosen sizes the fiber content ranges from 0.53 to 0.73 percent which is a little higher than the normal average Viatop66 fiber content of 0.3 percent (from previous research).

Based on the above performance results, the oil palm fiber size of 300μm gave the overall best performance in terms of resilient modulus and stability and creep and met the requirements for NAPA SMA mix. The test results also show that

Table 8: Optimum Mix Properties

Size (μm)	Bulk Density	Stability (kN)	Resilient Modulus (MPa)
106	2.303	11.2	3220
180	2.313	8.2	2930
250	2.330	13.7	3175
300	2.306	12	3500
Control Viatop66	2.340	13.18	3963

Table 9: Optimum Percentage of Oil Palm Fiber

Size (μm)	for Bulk Density (%)	for Stability (%)	for Resilient Modulus (Mpa) (%)	Average, %
106	0.4 – 0.6	0.6 – 0.8	0.6 – 0.8	0.53 – 0.73
180	0.4 – 0.6	0.6 – 0.8	0.6 – 0.8	0.53 – 0.73
250	1	0.6	0.4 – 0.6	0.67 – 0.73
300	0.6 – 0.7	0.6 – 0.7	0.6	0.60 – 0.67

the performance of SMA with oil palm fiber is quite comparable to SMA with the imported Viatop66 fiber in terms of dynamic load resistance. Eventhough the number of load cycles (5400) to reach the 3% strain for the oil palm fiber mix is slightly less than that of Viatop66 fiber (7461), it is certainly very much higher than the SMA mix without any fibers. This indicates that the oil palm fibers definitely improve the dynamic load resisting capability of the SMA mix compared to the one without any fibers.

It was also observed that nearly all the properties show a maximum when plotted against the different percentages of oil palm fiber. This could be due to the increased resistance to Marshall compaction of high fiber contents causing reduction in air voids. Thus quite a number of the properties were reduced at a higher airvoids.

The overall performance of oil palm fibers in SMA gives an indication that the is a very promising market for the use of oil palm fiber in road mix. Since the oil palm fibers are inexpensive the overall cost of the SMA mix could be almost comparable to the conventional mix. One of the major outcome of this research is the ability of the oil palm fibers in preventing the drain down of binders while improving the stability of the mix which should lead to improved field performance. In addition to that the chemical composition of the oil palm fibers show that they do not contain any deleterious elements that may cause serious problems when used in asphalt mixes. The low value of moisture content, and the alkali solubles in the oil palm fiber may assist resisting the higher heat temperatures of the asphalt.

Figure 1: Resilient Modulus Vs Percentage of Oil Palm Fiber

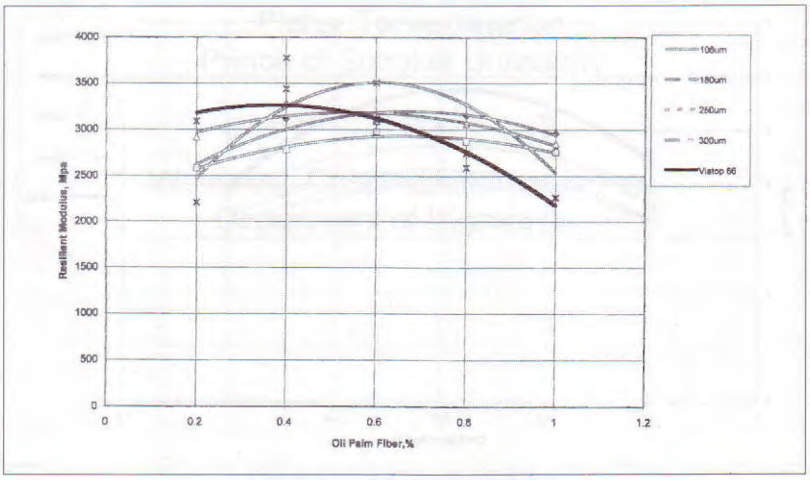


Figure 2: Marshall Stability Vs Percentage of Oil Palm Fiber

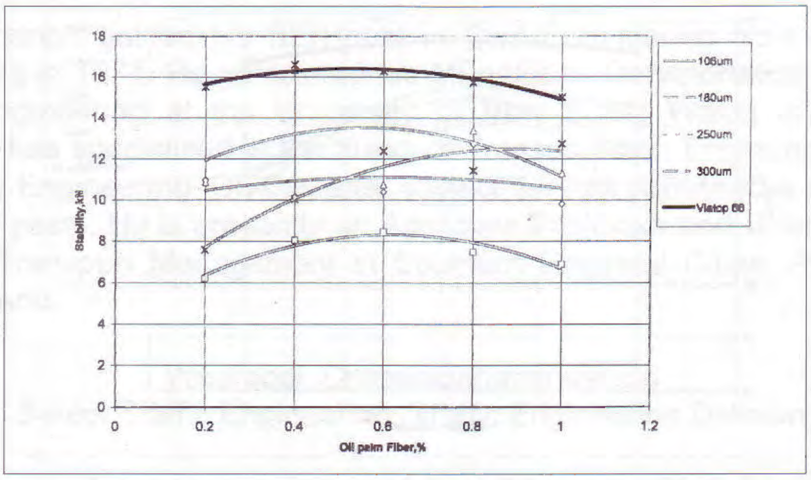


Figure 3: Bulk Density Vs Percentage of Oil Palm Fiber + A128

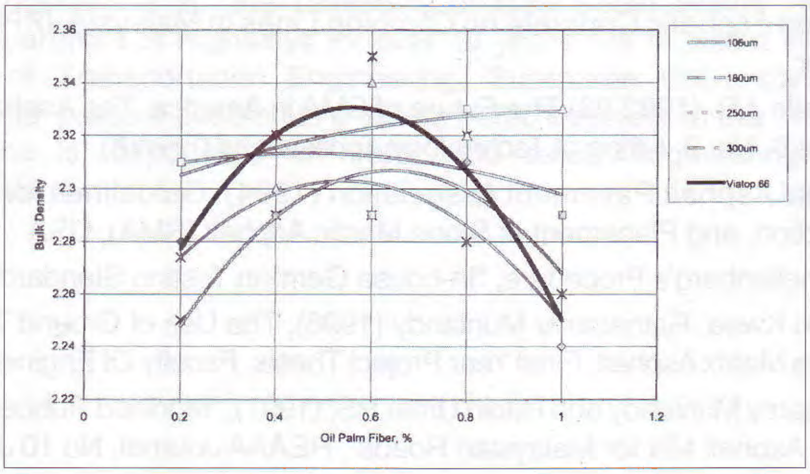


Figure 4: Flow Vs Percentage of Oil Palm Fiber + B168

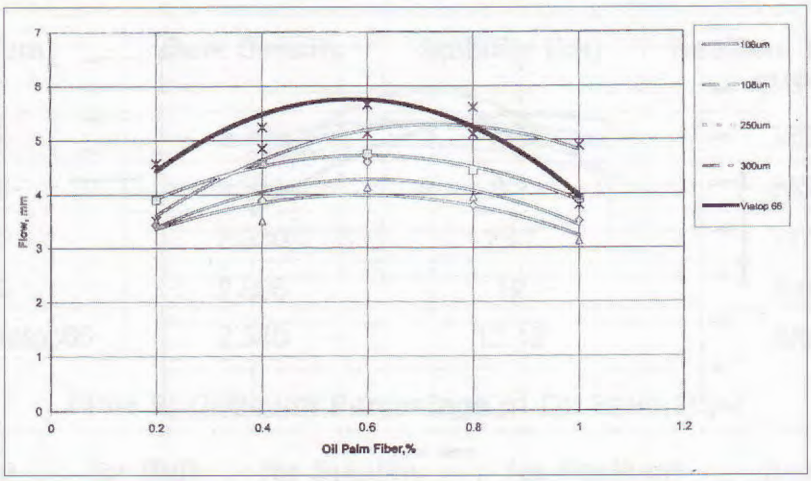
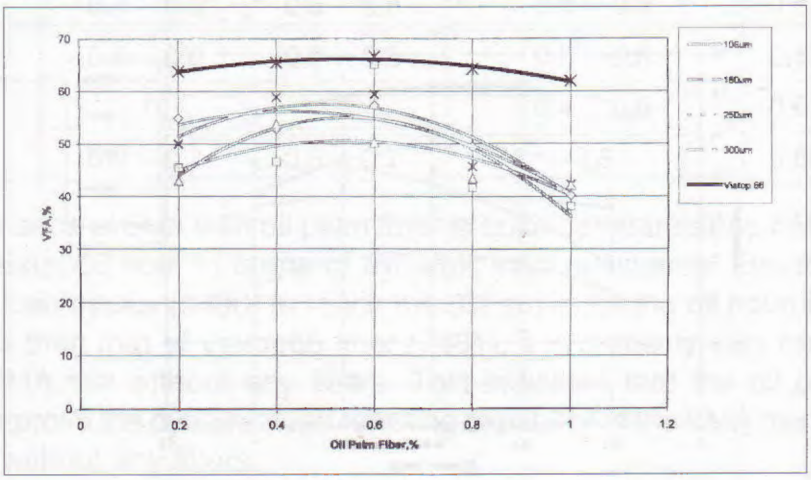


Figure 5: Voids Filled With Asphalt (VFA) Vs Percentage of Oil Palm Fiber



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BUS SAFETY IN THAILAND
(Road Safety)

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1. INTRODUCTION

Road accidents or road crashes are problems of societies with motorized forms of transport. The World Health report indicates that in 1998, there were 1,171,000 deaths resulting from road crashes worldwide or 2.2% of the total number of deaths from various diseases in all countries which amounts to 53,929,000. In addition, the number of injuries were estimated at around 10 millions (World Health Report, 1999). In many countries, road accidents are now commonly the second largest cause of deaths for the core age group (5–44 years) and the problem has been considered by the World Health Organization to be of epidemic proportions,(Road accidents cost countries between one to three percent of annual Gross Domestic Product (GDP) and annual losses due to road crashes have been a serious economic drain and problem for many developing countries (Ross, 1998). Ross estimated that these costs were at least US$20bn per year.

The severity of the problem is still increasing in the developing countries while the developed countries have largely kept the problem under control. However, in its World Disaster Report, the International Federation of Red Cross and Red Crescent has predicted that road traffic accidents would emerged as the 3rd leading cause of disease or injury burden in 2020 from its 9th ranking in 1990. (World Disaster Report, 1998).

This paper describes the results of a Thai bus safety study (Taneerananon, 1999). Bus accidents, their causes and suggested remedial measures are discussed.

2. ROAD CRASH SITUATION IN THAILAND

2.1 Magnitude of the Problem

Records of the Office of National Police and The Department of Highways (Department of Highways, 1998) indicate that, the number of crashes increased dramatically from 24,132 cases in 1987 to 102,610 cases in 1994 (See Table 1 and Figure 1) when it peaked. During the same period the number of fatalities has gone from 2,104 to 15,176, it reached the peak number of 16,727 and declined to 12,234 in 1998.

Table 1 : Thailand Traffic Accident Statistics, 1987 - 1998

Year	Bangkok Metropolis			Other Provinces			Whole - Kingdom		
	Accidents	Killed	Injured	Accidents	Killed	Injured	Accidents	Killed	Injured
1987	19,745	752	6,333	4,387	1,352	2,256	24,132	2,104	8,589
1988	31,175	817	9,565	4,114	1,198	3,939	35,289	2,015	13,504
1989	31,709	917	10,005	6,388	4,451	3,076	38,097	5,368	13,081
1990	33,064	949	10,701	7,417	4,816	7,551	40,481	5,765	18,252
1991	38,355	1,057	10,778	7,946	5,276	8,777	46,301	6,333	19,555
1992	46,743	983	11,025	14,586	7,201	9,677	61,329	8,184	20,702
1993	64,006	1,011	11,031	20,886	8,485	14,299	84,892	9,496	25,330
1994	72,359	1,290	18,849	30,251	13,856	24,692	102,610	15,146	43,541
1995	64,469	1,284	21,697	24,898	15,443	29,021	94,362	16,727	50,718
1996	60,308	1,069	23,314	28,248	13,336	26,730	88,556	14,405	50,044
1997	54,324	903	20,933	28,012	12,933	27,828	82,336	13,836	48,761
1998	46,800	732	18,920	26,925	11,502	33,618	73,725	12,234	52,538

Source : Office of the National Police, Office of the Prime Minister and Traffic Engineering Division, Department of Highways (1998).

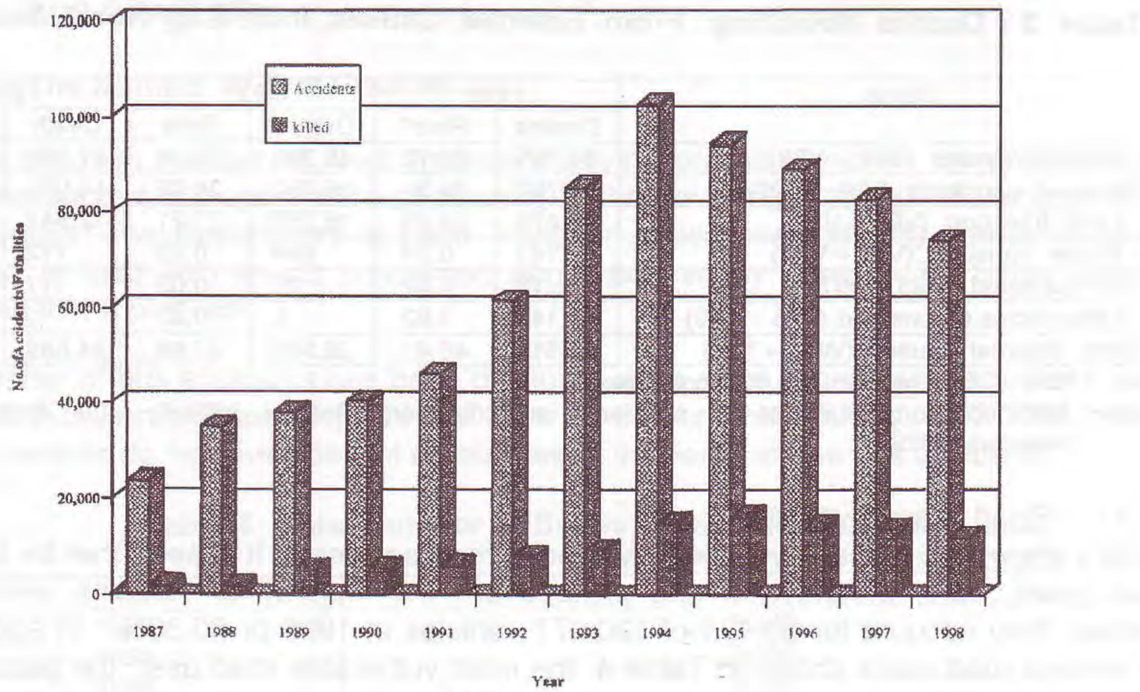

Figure 1: Trend in Number of Crashes and Fatalities

Table 2 shows the ten major causes of death in Thailand in 1998 . It is seen that the external causes (See Table 3) which include various forms of accidents, poisoning homicide etc., are the second major cause of death. Transport accidents are a significant part of the external causes causing 13,073 out of 37,662 deaths. Of these, road traffic accidents accounted for 12,942 deaths or 99% of the transport related deaths in 1998.

Table 2 : Major Causes of Death in Thailand in 1998

Cause	No. of Deaths	Death/100000 Population
1 Diseases related to blood circulation (I00 – I99)	59,601	98.57
2 External causes: Accidents etc. (V01 – Y89)	37,662	62.29
3 Cancer (C00 – D48)	26,478	43.79
4 Respiratory Diseases (J00 – J98)	20,415	33.76
5 Infectious & some parasitic Diseases (A00 – B99)	16,894	27.94
6 Diseases of blood & blood production organs etc. (D50-D89)	8,806	14.56
7 Digestive system (K00 - K92)	8,647	14.30
8 Diseases of Nervous System (G00 – G98)	8,400	13.89
9 Diseases of Reproductive & Urinary System (N00 – N98)	5,242	8.67
10 Diseases of endocrine glands etc.(E00 – E88)	4,941	8.17

Source : Division of Health Statistics, Ministry of Health. Compiled by Medical Institute for Accidents & Disasters (1999)

Table 3 : Deaths Resulting From External Causes Including Road Accidents

Cause	1996		1997		1998	
	Deaths	Rate*	Deaths	Rate	Death	Rate
All external causes (V01 - Y89)	44,295	74.72	45,298	75.76	37,662	62.29
1 Transport accidents (V01 – V99)	16,782	28.31	16,792	28.09	13,073	21.62
- Land transport (V01 – V89)	14,479	24.43	16,268	27.21	12,942	21.40
- Water transport (V90 – V94)	143	0.24	499	0.83	112	0.19
- Air transport (V95 – V97)	13	0.02	16	0.03	17	0.03
- Other forms of transport (V98 – V99)	2,147	3.62	9	0.02	2	0.00
2 Other external causes (W00 – Y89)	27,513	46.41	28,506	47.68	24,589	40.67

Note : * Rate = Deaths per 100,000 population

Source : Modified from Statistics of accidents and disasters (Medical Institute for Accidents & Disasters 1999)

2.1.1 Road users involved

Table 4 shows the types of vehicles involved in road accidents. It is seen that for the past three years, cars, motorcycles and pickups are the majority of vehicles involved in crashes; they account for 96,424 of 120,077 vehicles in 1998 or 80.30%. In addition to the various road users shown in Table 4, the most vulnerable road user, the pedestrians are also heavily involved in road crashes. In 1997, police records show that there were 4,155 pedestrians involved in crashes, of these 2,626 were in Bangkok Metropolitan.

Table 4: Types of Vehicles Involved in Road Crashes 1996-1998

Unit: vehicle

Rank	Type of vehicle	1996	1997	1998
1	Car	44,179	42,103	36,538
2	Motorcycle	43,964	41,939	37,414
3	Pick up	28,151	25,484	22,472
4	Van	2,139	3,524	2,975
5	Big truck	7,276	5,708	4,102
6	Big bus	4,999	4,414	3,717
7	Taxi	3,953	4,210	4,476
8	Truck (6 wheel)	4,576	3,794	3,157
9	3-wheel Paratransit/tuk tuk)	2,684	2,187	1,717
10	Farm vehicle (E-tan)	268	309	282
11	Bicycle	1,339	1,311	1,319
12	Tri shaw	735	522	500
13	Others	1,294	1,157	1,408
	Total	145,557	136,662	120,077

Source: Accident analysis and prevention unit, Office of Engineering and Safety, Department of Land Transport, and Information Center, Office of the National Police (1999)

2.2 Costs of Road Accidents

The economic losses due to road accidents are immense, as mentioned in section 1, that the costs to the economy of a country is between 1-3% of GDP. In 1997, a road safety master plan carried out for the Ministry of Transport and Communications (MOTC)showed the economic loss to the country at 106,368 million baht per year, this is equivalent to 3.41% of the GNP for 1993 (Kingdom of Thailand, 1997).

In summary, it can be said that for the past decade (1990-1999) road traffic accidents have costed Thailand more than 1,000,000 million baht and 102,126 lives.

3. BUS CRASHES

3.1 The Number of Bus Crashes

Despite the high number of road crashes involving private vehicles, crashes involving public transport is a major source of concern to the travelling public particularly on inter-city journeys. The Department of Land Transport which oversees the operation of bus transport is also very much concerned about bus safety, despite its rather passive approach to the problem.

The number of bus accidents has been declining since 1994, significant reductions occur from 1995 onwards. Table 5 gives the trend in bus crashes during 1992-1998 period. Official records do not give account of fatalities or injuries from the bus accidents.

Table 5: Total Number of Buses Involved in Crashes

Year	Number of buses
1992	5,640
1993	6,895
1994	5,569
1995	5,510
1996	4,999
1997	4,414
1998	3,717

Source: Safety Division, Department of Land Transport

3.2 The Transport Company Bus Accidents

Table 6 shows road accidents involving buses of the Transport Company, a semi government enterprise which holds all the long distance route licenses, and its affiliates' buses. It can be seen that although the number of accidents have declined substantially in the last three years, fatality and injury figures have not followed. This trend suggests the increase in severity of bus accidents.

Table 6 : Accident Statistics of the Transport Company and its Affiliates Buses/during Financial years 1990-1998

Financial	The Transport company buses			Affiliated buses			Total		
Year	No. crashes	Injuries	Fatalities	No. crashes	Injuries	Fatalities	No. crashes	Injuries	Fatalities
1990	603	145	36	185	553	240	788	698	276
1991	601	196	56	193	798	199	794	994	255
1992	582	138	47	273	1033	324	855	1171	371
1993	635	215	79	163	760	202	798	975	281
1994	630	254	57	199	849	273	829	1103	330
1995	500	179	50	123	533	112	623	712	162
1996	495	152	52	104	683	142	599	835	194
1997	432	187	51	98	710	136	530	897	187
1998	298	258	57	79	546	118	377	804	175

Source: The Transport Company Limited

3.3 Major Bus Crashes as Reported in Newspapers

In 1998, there were 32 major bus crashes in Thailand, resulting in 65 fatalities and 692 injuries. Inter-city Category 2 buses were involved in 9 crashes, urban buses in Bangkok 10 with the remainders comprising 8 cases of Inter-city Category 3 bus, 4 of tourist buses and 1 of private bus. Table 7 gives details of the casualties and types of crashes.

Table 7: Major Bus Crashes in 1998.

Type of service	Number of Casualties		Number of Crashes	
	Fatalities	Injuries	Hit other vehicle	Single vehicle
Category 2 bus	36	309	7	2
BMTA bus	5	133	5	5
Category 3 bus	18	127	3	5
Tourist bus	4	103	1	3
Private bus	2	20	1	-

Note: BMTA = Bangkok Mass Transit Authority; Category2 bus: run between Bangkok and the provinces; Category3 bus: run between the provinces.

From the table it can be seen that single bus accidents constitute about 50% of the total. It should be noted that in the case of Inter-city buses when the vehicle ran off the road and rolled over or ran into a road side object, its roll over strength becomes a critical factor; in many incidents the bus body was crushed by the force of impact.

The most serious accident in which there were 14 fatalities and 20 injuries was a collision between a category 2 bus and a 10 wheel truck, the accident occurred at 0330 hr; speeding and bald tyres were cited as the causes of accident.

3.4 Causes of Road Accidents

3.4.1 Police records of the causes of accidents

The causes of road accidents are collected by police when investigating a crash. Table 8 gives details of the causes of road accidents in 1997. The 3 major causes for the whole kingdom are : Speeding (29%), Abrupt Cutting-in (14%) and Improper Overtaking (11%). For accidents on the inter-city and inter-district highways, the three major causes are similar i.e. Speeding (39%), Abrupt Cutting-in (15%) and Failure to Indicate Intention (8%). For 1998, the figures for the 3 major causes for the whole country are 32.3%, 19.0% and 13.9% respectively.

Table 8: Causes of Road Accidents in 1997

Cause	Whole Kingdom	Bangkok Metropolis	Regions	Highway
Exceeding speed limits	23,408	11,889	10,568	951
Abrupt cut-in	11,627	7,131	4,002	494
Improper overtaking	9,222	6,996	2,160	66
Failure to indicate intentions	4,665	3,821	676	168
Disregarding traffic signal/sign/Marking	4,317	3,823	478	16
Disregarding stop sign at intersection	3,445	2,852	580	13
Not keeping to the left	2,909	2,646	262	1
Total	80,854	51,453	27,419	1,982

Source: Safety Division Department of Land Transport and Police Information Centre, Office of the National Police Force

3.4.2 Other information on the causes of bus accidents

Nearly all data related to road accidents are collected by the police. However, the Safety Division of the Department of Land Transport and the Traffic Engineering Division of the Department of Highways produce information on the causes of accidents from police records. In addition , the Safety Division of DLT compiles data on serious bus or truck accidents but does not publish them. The Transport Company produces information on the causes of their bus accidents in which they were the guilty party. These could be regarded as representatives of the causes of bus accidents.

Causes of Accidents of the Transport Company Buses

The Transport Company operates some 850 buses, some of which were involved in 298 crashes in 1998. Of these, 48 were single vehicle accidents (See Table 9) and 142 involved other vehicle (See Table 10). For single bus accidents, the three major causes are: speeding, poor visibility and slippery road with burst tyre ranks fourth. For accidents involving collisions with other vehicle, the three major causes are: failure to apply brake, speeding and poor visibility with the fourth being slippery roads. It can be seen that drivers' errors feature prominently and when combining with road environment factors of poor visibility and slippery road contribute to many accidents.

Table 9 : Single bus accidents involving the Transport Company and its affiliates' buses in 1998

Causes	No. of Crashes by Region						
	The Transport Company buses					Affiliated Buses	Total
	N	NE	C	S	E		
1. Speeding	2	5	1	2	1	-	11
2. Can not see	2	-	-	-	-	-	2
3. Slippery Surface	4	1	-	5	1	-	10
4. Burst tyre	2	-	1	-	-	4	7
5. Lost control + Avoiding other vehicle	-	2	-	-	1	17	20
6. Others + Driver Sleepiness	1	5	2	7	-	5	20
7. Failure to apply brake	-	1	2	-	-	-	3
8. Vehicle cuts in front at close range	-	-	1	-	-	-	1
Total	11	14	7	14	3	26	74

Source: The Transport Company Ltd.

Table 10 : Causes of Accidents of the Transport Company Buses involving Other Vehicles

Causes	No. of Crashes by Region					
	N	NE	C	S	E	Total
1. Fail to brake	10	11	14	10	1	46
2. Speeding	15	10	7	6	1	39
3. Can not see	4	5	4	1	-	14
4. Slippery road	5	1	-	5	1	12
5. Abrupt cutting	5	-	5	1	-	11
6. Change lane suddenly	-	3	-	-	-	3
7. Avoid other vehicle	-	2	-	-	-	2
8. Others+drowsiness+drive in wrong lane	2	5	3	3	2	15
Total	41	37	33	26	5	142

Source: The Transport Company Ltd.

3.4.3 Unsafe and unforgiving roads and road environment

Studies in the UK and USA show that the contribution of human factor alone to road crashes amounts to 65% and 57% respectively, the combined factors of human error and road defects contribute to 24% and 27% of the total crashes (Ogden 1996). For Thailand, drivers' fault accounts for 82.5% of the total road crashes in 1998 (See Table 11).

Table 11 : Factors involved in road crashes in Thailand in 1998

Factor	%
Driver's faults	82.5
Vehicle defects	0.6
Road & road environment	1.5
Others	15.4

Source: Information Centre, Office of the National Police 1999

4 STRATEGIES FOR COMBATING THE ROAD CRASHES

4.1 Road Safety Master Plan

The grave situation of road crashes which continues with unacceptably high number of fatalities has finally led to the development of a Road Safety Master Plan (RSMP) (Kingdom of Thailand, 1997). The RSMP consists of extensive list of issues which address road safety as a whole. Bus safety aspects are covered under many programmes including drivers training and vehicle safety. MOTC in 1997 proposed 9 programs of activities to be implemented over a five year period, with a total budget of 9,850 million Baht. These programmes to be implemented over a 5 year period are as follows (Ministry of Transport, 1997):

- Road Safety Economy, Policy and Organization — Programme A
- Legislation and Law Enforcement — Programme B
- Accident Analysis and Research — Programme C
- Driver Training and Licensing — Programme D
- Traffic Training in Schools — Programme E
- Public Information — Programme F
- Vehicle Safety — Programme G
- Infrastructure — Programme H
- Emergency Treatment of Accident Victims — Programme I

4.2 Proposed Remedial Measures for Bus Accident Problem

From the bus safety in Thailand study (Taneerananon, 1999) the following measures are proposed to address the bus accident problem in Thailand. They cover areas of driver behaviour and fitness, road environment improvements, vehicle safety and traffic law enforcement.

4.2.1 The Driver Factor

Competency and Behavioral Controls

A stricter driving test and monitoring is suggested. Under the Land Transport Act, applicants are required to pass 38 of the 50 questions or 75%. It is noted that applicants for a public vehicle licence need not have prior experience in driving, they only need to be 22 years of age which was recently reduced from 25 and if they do not possess junior

high school certificate (9 years at school) they are required to sit for a one day training organized by the Department of Land Transport and pass the written and simple practical tests on the second day. For those with 9 or more years of education, only about half a day is required for training, this is then followed by written and practical tests in the afternoon of the same day. The simple driving tests are conducted off roads usually in a small compound. Thus theoretically, new drivers who pass the test can go on the road the next day with little or no experience on the actual driving on the road. There is therefore a clearly needed improvement in the issue of driving licence for public transport vehicles. Driving experience should be made a requirement in addition to competency in driving.

It is understandable that not many drivers surveyed liked the idea of stricter driving tests scenario (6%) but the Department of Land Transport has an obligation to provide the travelling public with the maximum safety possible.

Fitness Checks

Medical check ups for driving licence application should be performed by recognized medical institutions, and not just by any doctor as in the present situation. This is to ensure that check ups are strictly and properly carried out. This may incur some extra inconvenience to the applicants but then the importance of a licence can not be overestimated.

For drivers on the road, the interview results reveal that 55% of the drivers never had any medical check up, and a disturbing 9% failed the 20 m eyesight test. These figures point to the need to monitor the health of drivers. Annual check up should be made a requirement for drivers on certain age group. The Transport Company's policy on medical check up on each driver's birthday month is to be commended.

Provision of Rest Area for Drivers

Drivers fatigue has been shown to be a significant cause of bus crashes. The Department of Labour Control specifies that within a 24 hour period, a driver is allowed to drive for a maximum of 4 hours , after a break of not less than 0.5 hour the driver can drive for another maximum of 4 hours. The provision of well designed rest areas at appropriate locations will enhance the compliance of the law.

4.2.2 Improving the Road Environment

Good Roadside Hazard Management

Many of the single bus accident could have been avoided or at least reduced in severity if the road are well designed and managed. For instance in November 1998 , a tour bus with 90 people on board ran off the road and fell about 10 meters, 85 were injured 4 seriously. In this case the crash barrier gave in and the driver was suspected of driving under the influence of alcohol. Another accident in which 10 people were killed and 30 injured occurred in April 1999 when a tour bus skidded off the road and hit a power pole. A 'forgiving roadside' could have averted the tragedy. Thus a good roadside hazard management programme should be designed and implemented by the concerned authorities.

In addition, black spots on highways should be dealt with especially where bus crashes have occurred.

4.2.3 The Vehicle Factor

Vehicle Inspection

Vehicle roadworthiness is an important element in bus safety. Despite the encouraging results from the survey which indicate that the bus fleet in Thailand is in relatively good shape, some defects e.g. tyre burst was still a significant event leading to bus crashes. Present annual bus inspection should be enhanced. While most provincial DLT offices are well equipped with inspection instruments and facilities, problems are that at present many are out of order or are not properly calibrated. These expensive equipments should be made to function as intended. The DLT could set up an efficient maintenance task force to help look after the 75 provincial offices nationwide.

Vehicle Design

In crash situation the integrity of the whole bus body including its interior becomes critical. Regulations on critical aspects of bus safety to render it crashworthy should be looked into by the Thai government. These aspects include installation of safety belts, seat strength, roof strength, anti-locked brakes and emergency exits. The UN ECE regulations can be used as guidelines to develop these regulations. For example, UN ECE regulation 66 which deals with roof strength should be looked into by the Thai government as many bus crashes had manifested that the roofs caved in on passengers. Installation of seat belts in new buses or retrofitting existing buses would improve safety of passengers in a cost –effective manner during crashes or prevent injuries in case. of sudden braking and should be made a requirement as car seat belt wearing is already.

Use of Technology

The Tachograph. It is clear from the survey, the Transport Company and police records that speeding is the major cause contributing to bus crashes , it thus seems appropriate that serious measure should be taken to address the problem of speeding. Tachograph, a device used to record speed and duration of a journey should be made a requirement for buses ,particularly inter-city buses. The tachograph in essence is a 'silent cop' who the bus driver reluctantly takes with him on his trip.

Flashing Light. A system of mechanical-electrical mandatory installation on the bus to send out flashing signals on its roof top when speed limits are being exceeded can help control drivers' behaviour. The practice is used in many places including Singapore and Japan. There is however still a need to have police present to book the speeding driver.

4.2.4 Traffic Law Enforcement

Traffic and Transport law enforcement forms an essential part of accident prevention. Without strict law enforcement, it would be hard to keep speeding and drunk driving under control, Australian experience indicates that for education or publicity campaigns to work, it must be accompanied by enforcement. However, effective law enforcement requires manpower and resources. The study team 's investigation reveals that the highway police who are responsible for enforcement on the highways are ill-equipped to do their job, lacking in both manpower, vehicles and equipment. Interviews with officers at the Highway Police Station 3 in Hatyai confirmed that of the total police force of 35 and 14 vehicles and 2 radar speed guns, only 20 men and 9 vehicles are deployed to patrol about 900 km of road, they work day and night shifts without holidays. The remainder of the force are used to perform other duties including secretarial works, radio communication and security works. There is a need to quantify what resources are needed for effective enforcement and would they be cost-effective in bus accident prevention.

4.3 Setting up an Accident Investigation Unit

Serious accidents including bus accidents are required to be reported to the Department of Transport by the DLT provincial chiefs where the accident takes place. However, there is no systematic investigation into the cause of these accidents. Thus there have been little knowledge gained on how to deal with the problem and prevent similar problem from occurring. The set up of an accident investigation unit will help Thailand gain valuable experience and information required to better deal with one of its most critical problems.

5. CONCLUSION

The paper describes the road crash situation in Thailand. It gives account of bus accident problem, its causes and suggests a number of measures to deal with the problem. These measures address the issues of drivers' competency and fitness, road improvements, vehicle safety and traffic law enforcement.

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DEVELOPMENT OF A PRECAST CONCRETE LINING TECHNIQUE USING PRESTRESSED CONCRETE STRUCTURES

(Road Tunnels)

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1. INTRODUCTION

Because urban tunnels in Japan must be constructed under soft geological conditions with few self-supporting properties, shield tunneling methods, which are highly stable and scarcely affected by geological changes, have recently begun to be used more frequently. However, shield tunneling methods commonly require great machinery and primary lining expenses, so the tremendous construction cost becomes a problem when constructing a tunnel with a large aperture such as a road tunnel. Under these circumstances, we have been conducting research and development of the "Prestressed Concrete Segmental Lining," a rational primary lining system to produce a high economic efficiency.

The Prestressed & Precast Concrete Segmental Lining (P&PCSL) is used for shield tunnels. Its primary feature is that it integrates segments into one ring by introducing prestress in the tunnel circumferential and longitudinal directions. Introducing prestress enables the elimination of joint metals and reduces the volume of reinforcement, thus reducing the manufacturing cost of precast concrete segments. It also enables quality improvement and labor saving in assembly and provides greater adaptability for tunnels with large apertures, where deformation due to self weight is a problem. The P&PCSL has been implemented in actual construction work after undergoing various performance tests and workability verification tests.

2. P&PC SEGMENTAL LINING OUTLINE

2.1 Outline of the Method

The P&PCSL provides a lining ring of post-tensioned PC structure by assembling a concrete ring segmented, giving it tension, and fastening it by inserting a prestressing single strand into the sheath that is preliminarily embedded in the precast concrete segment.

Because an unbonded prestressing strand with low friction loss, is used for the prestressing strand, sufficient prestress can be introduced if tension is applied to only one position on the whole circumference. Furthermore, by using a combined anchoring device made of cast iron that has the tension side and fixing side integrated into one piece (X anchor) by embedding it in the segment, the reinforcement in the segment can be simplified and workability of tensioning can be improved.

A system in which a segment can be pressed against and contacted to an existing segment using a shield jack is used to assemble segments; no bolt joints are used between rings or between segments. Figure 1 shows a schematic drawing of the P&PCSL, Photo 1 shows the X anchor, and Photo 2 shows the segment with anchoring device.

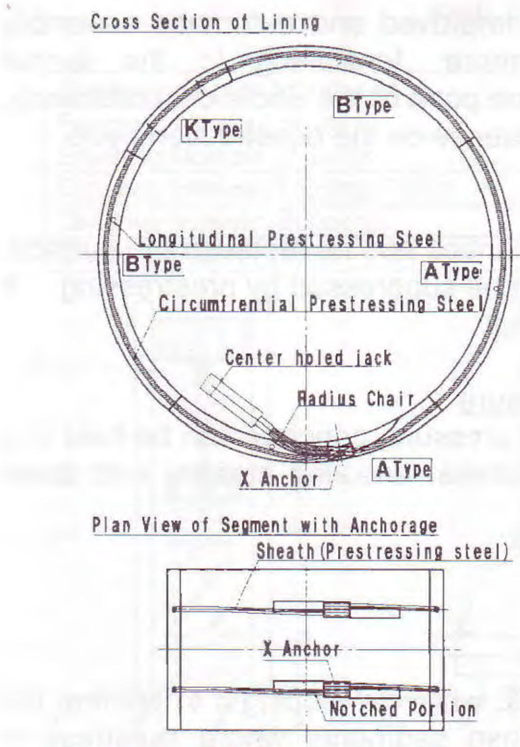

Figure 1 : P&PC Segmental Lining

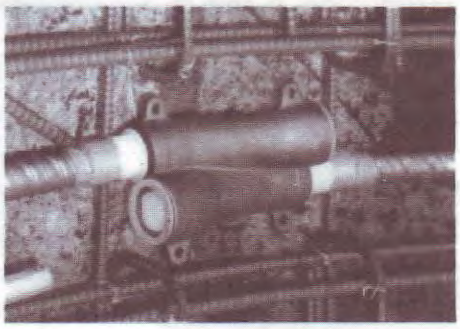

Photo 1 : X Anchor

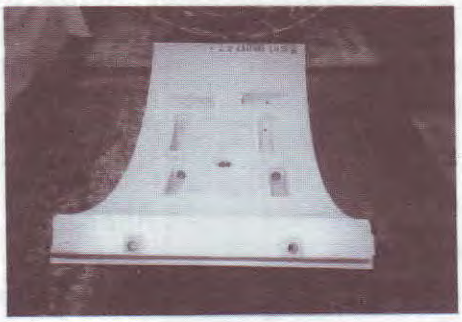

Photo 2 : Segment with Anchorage

2.2 P & PC Segmental Lining Features

Features of the P & PCSL are described below.

2.2.1 Economic efficiency

Because segments are integrated into one piece by introducing prestress, joint metals can be eliminated. Also, the volume of reinforcement to obtain the same bending performance can be reduced largely as compared with RC structures. Furthermore, the height of the segmental lining can also be reduced in segments with a medium to large aperture. Owing to these features, the segment manufacturing cost can also be reduced. In addition, this segment is also suitable for non-inner concrete lining, so a total cost reduction can be achieved by reducing the outer diameter of the tunnel.

2.2.2 Quality

Cracking in the concrete can be suppressed by introducing prestress. Furthermore, a segment that has excellent roundness and water-tightness with small deformation of the ring during assembly can be achieved because joint gaps are very small. Moreover, as an unbonded structure, it is tough with a high stability, and joints are resistant to breakage even under a high load. In the tunnel longitudinal direction, in particular, such flexibility will help improve anti-seismic durability.

2.2.3 Workability

Segments are assembled without any bolts; only fastening with a shield jack is

required. As a result, workability can be improved and automatic assembly can be easily implemented. Furthermore, tensioning in the tunnel circumferential direction is applied at only one point of the whole circumference, so workability can be improved with little influence on the construction cycle.

2.2.4 Segment with a smooth interior

The segment has an interior with few irregularities and no metal on the surface. It is highly water-tightness, and cracking can be suppressed by prestressing. It is thus suitable for a non-inner concrete lining.

2.2.5 Segment to resist internal water pressure

For tunnels subjected to high internal water pressure, concrete can be held in a fully compressed state by introducing prestress, ensuring stability and water -tightness.

3. OUTLINE OF EXPERIMENTS

We performed various tests on the P&PCSL while developing it to confirm the basic performance and workability of those segments where prestress is introduced in the tunnel circumferential and longitudinal directions. The results of these various tests are summarized in Table 1. Incidentally, the results of bending tests on segment joints, where features of the structure of the P&PCSL is clearly shown, are reported in this section.

3.1 Bending Test on Segment Joints

3.1.1 Outline of the test

We performed a bending test on segment joints by applying prestress to the arch-formed beam jointing two A-type segments (using two prestressing strands) and applying concentrated loads on two points, i.e. movable fulcrums at both ends. The load applied, horizontal and vertical displacements, tensile force, surface strain of concrete, and joint gaps were measured. Test procedures are shown in Table 2, an outline of the test apparatus is presented in Figure 2, and testing is shown in Photo 3.

Table 1 : Performance Tests

Outer Diameter of 2400mm Performance Verification Test	Circumferential and Longitudinal Tensile Tests Joint Performance Test Rigidity/ Durability Tests
Outer Diameter of 2950mm Performance Verification Test Workability Verification Test	Single - Unit Bending and Joint Bending Tests Ring Loading Test Jack Thrusting Test, Hanger Metal Pulling Test PC Grouting Test Segment Assembling Test
Outer Diameter of 2700mm Performance Verification Test	Internal Water Pressure Loading Test

Table 2 : Test Procedures

Tensioning Force Introduced	86.3 kN per Strand
Resisting Moment of Joints	10.8 kN-m
Breaking Moment of Joints	17.0 kN-m
Distance between Loading Points	900 mm
Distance between Supports	2653.5 mm
Breaking Load of Joints (Pj2)	29.4 kN

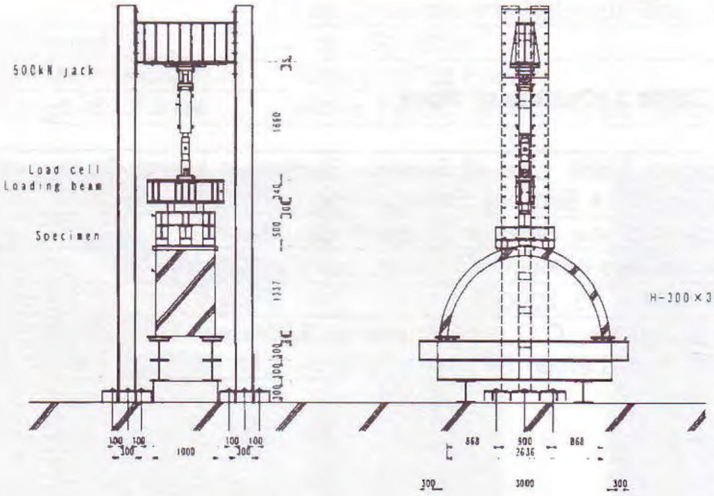

Figure 2 : Joint Bending Test

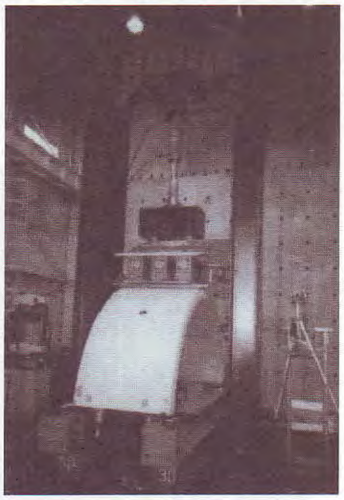

Photo 3 : Joint Bending Test

3.1.2 Test results

A load was applied until the joint broke under a load of Pmax = 37.1 kN: the load was then removed. The designed bearing force Pj2 using an unbonded prestressing strand is 29.4 kN, confirming a sufficient bearing force. Furthermore, the horizontal displacement was restored to the initial state before loading (0 mm) when the load was reduced to 0 kN because prestress is introduced, confirming that an unbonded structure has high stability. (See Figure 3.)

The rotation spring constant of segment joints was greater than that calculated using the empirical formula of Leon halt, et al. (See Figure 4.)

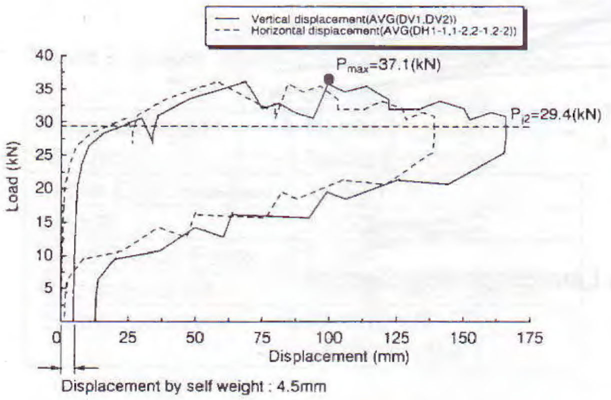

Figure 3 : Load vs. Displacement Curves

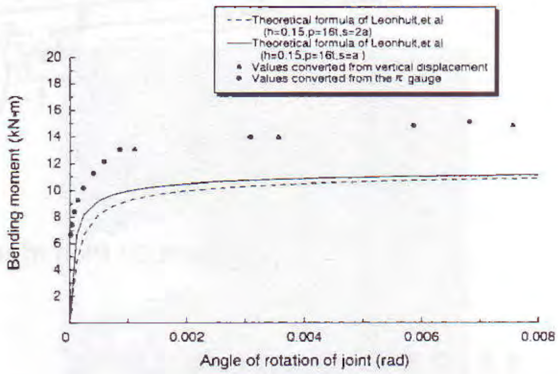

Figure 4 : Bending Moment and Rotating Angle

4. ACTUAL CONSTRUCTION

4.1 Outline of Work

After undergoing various performance verification tests and workability verification tests, the P&PCSL was adopted for the first time in a 50 m segment of sewage construction work ordered by the Osaka Prefectural Office. The work is summarized Table 3.

Table 3 :Outline of Work

Project Title	On'chigawa-Higasi Trunk Line of Sewage System in Lower Stream of Neyagawa Basin (No. 4 Section), Sewage Pipe Construction Work
Owner	Osaka Prefectural Office, Sewage Office for East Basin
Work Site	Koorigawa 1-chome to Kakiuchi 1-chome, Yao City, Osaka
Period of Work	Dec. 18, 1997 to Mar. 15, 2000
Contents of Work	Finished I.D. 2,200mm, O.D. of Excavation 3,989mm, Earth Pressure Balance Shield, Total Length 1,012.8m, Initial 50m for P&PCSL Method

4.2 Working Conditions

Overburden above the shield is 11 to 12 m, with the soil in the shield excavation point having an upper half consisting of complex alternate layers of diluvium sand and clay and a lower half consisting of gravel. Gravel has an N value of 40 to 60 and a maximum pebble size of 50 mm.

On the plan, the front half with a length of 25 m consists of a straight line while the latter half with a length of 25 m consists of a curved line with R = 200 m. The gradient in the upright view is 0.8%, where excavation was made while climbing the slope. A plan of the section constructed using P&PCSL is shown in Figure 5.

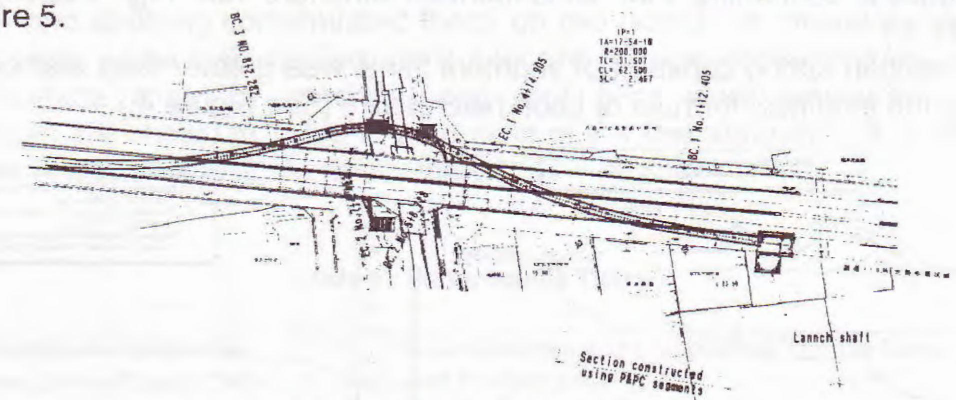

Figure 5 : Plan of the Launch Driving Section

4.3 P & PC Segmental Lining

The major specifications of the P&PCSL used for this project are shown in

Table 4. The temporary placement is shown in Photo 4.

Table 4 : Major Specifications of the P&PCSL

Form	Outer Diameter 2,950 mm, Height 150 mm, Width 1000 mm
Division	4 Segments plus 1 Key
Tensioning Material	Unbonded Prestressing Single Strand (1T-12.7 mm). Two Circumferential Strands/Ring, Four Longitudinal Strands/Ring.
Concrete	F'ck = 50 N/mm^2
Circumferential Joint	Joining of Flat Faces
Longitudinal Joint	With a Tenon / Mortice at the Center of the Joint

Photo 4 : Temporary Placement

Photo 5 : Earth Pressure Balanced Shield

4.4 Shield Machine

Table 5 summarizes the specifications of the shield machine used. Photo 5 shows an overall view of the shield machine, and Photo 6, the temporary support jack. A boltless assembly method is applied when the P&PCSL is used, so temporary support jacks are installed at the top of each shield tail section. The rest of the mechanism is the same as that of the shield machine used for conventional reinforced concrete segmental lining bolted .

Table 5 :Major Specifications of the Shield

Type of Shield Machine	Earth Pressure Balanced Shield
Outer Diameter	3,080 mm
Length	5,000 mm
Total Thrust Force	8 MN
Cutter Support	Center Shaft System
Screw conveyor	With Shaft (470 mm Dia.)

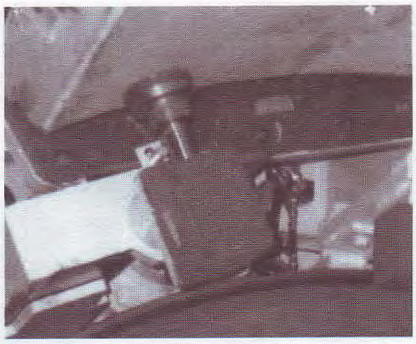

Photo 6 :Temporary Support Jack

4.5 Construction Results

4.5.1 Workability of assembling the P&PCSL

To assemble the P&PC lining segments, a system in which segments are assembled by pressing a new segment against the existing segment in turn using a shield jack was adopted. A new segment was easily aligned with the existing segment by matching the marks provided in the tunnel longitudinal sheath position. Temporary support jacks were used as auxiliary tools to secure sufficient safety after the upper segments were fastened using a shield jack. The workability for inserting the K type segment has been improved by placing the segment on either side outward with an allowance for the tenon (4 mm) left between rings.

Photo 7 shows assembling the B-Type segment, and Photo 8, assembling the K-Type segment.

Photo 7 : Assembling the B Type Segment

Photo 8 : Assembling the K Type Segment

4.5.2 Inserting, tensioning, and fastening unbonded prestressing strands

An unbonded prestressing strand was inserted by one or two workers pushing it manually. To tension unbonded prestressing strands, the required tensile force was first introduced then the tensioning jack was released so that the wedge was pulled in to fasten the strand. Photo 9 shows inserting an unbonded prestressing strand, and Photo 10, tensioning in the tunnel circumferential direction.

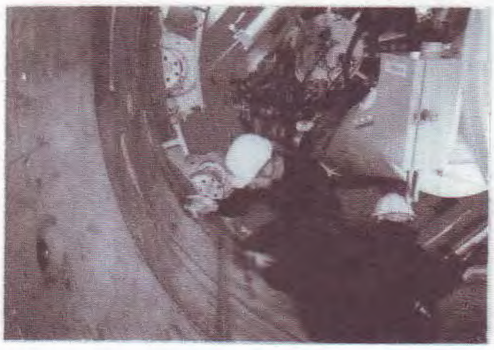

Photo 9 : Inserting a PC Strand

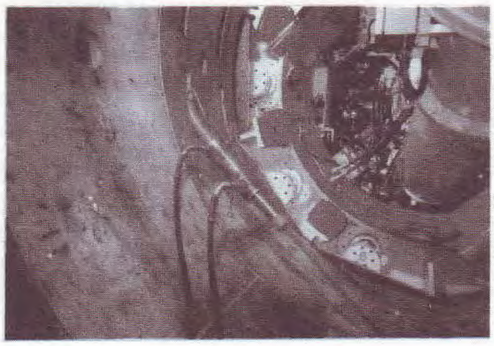

Photo 10 : Circumferential Tensioning

4.5.3 Results of on-site measurement

Prestress was measured in the tunnel circumferential and longitudinal directions using a concrete strain gauge and load cell at two intermediate points within the range of a total of 50 rings. Furthermore, the internal dimensions of the tunnel were measured upon completion.

The distribution of concrete surface strain with prestress introduced is shown in Figure 6. An increasing trend of compressive strain due to the introduction of prestress (calculated value 23 μ) was detected.

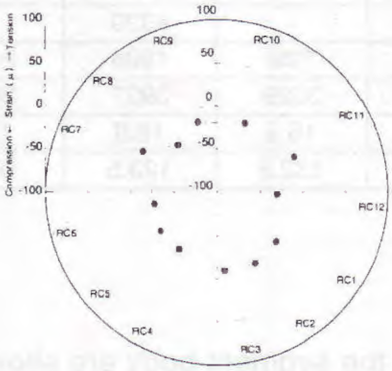

Figure 6 :Distribution of Concrete Strain

Photo 11 :Overall View Inside the Tunnel

5. SAMPLE TRIAL DESIGN OF ROAD TUNNEL

5.1 Study Conditions

A trial design was prepared for a case where the P&PCSL is applied to a two-lane road tunnel. Table 6 shows the study conditions. Two types of cross sectional form are used, round and lateral oval types. The forces acting on the cross section were calculated using a method based on the average rigidity uniformed ring vs. ground spring model for each of the P&PCSL and RC segmental lining bolted.

Table 6 : Study Conditions

Overburden	m	20
Unit Weight of Soil	kN/m^3	19
Submerged Unit Weight of Soil	kN/m^3	9
Coefficient of Lateral Earth Pressure		0.5
Surcharge	kN/m^2	10
Coefficient of Ground Reaction	N/cm^3	30
Underground Water Level	m	5.0
Allowable Compressive Stress of Concrete	N/mm^2	19
Allowable Tensile Stress of Reinforcing Bar	N/mm^2	200
Allowable Compressive Stress of Reinforcing Bar	N/mm^2	200

Table 7 : Study Results

Study Case	Unit	CASE.1 (Round)		CASE.2 (Lateral Oval)	
		P&PCSL	RCSL	P&PCSL	RCSL
Width / Height of Segment	mm	1500/400	1500/450	1500/675	1500/850
Cover / Effective Height	mm	50/350	50/400	50/625	50/800
Positive/Negative Reinforcement	cm^2	25/25	45/45	60/60	119/119
Prestressing Steel	nos.	21.8mm×4	-	21.8mm×6	-
Preset Tension / Eccentricity	KN/cm	1280/5.0	-	1920/22.5	-
Moment of Eccentricity	kNm	640	-	4320	-
Bending Moment (Max.)	kNm	554	709	1986	2795
Axial Force (at the Max. Bending)	kN	3549	3529	3927	3666
Compressive Stress of Concrete	N/mm^2	17.8	16.5	16.9	13.1
Tensile Stress of Reinforcement	N/mm^2	21.4	132.2	123.5	196.1

5.2 Study Results

Investigation results of the intensity of stress in the segment body are shown in Table 7. By introducing prestress, the segmental lining height can be reduced by 50 mm for a round type and by 175 mm for an oval type. Introducing prestress was found to be more effective in those structures where the bending moment prevails, such as the lateral oval type. Comparing the round and lateral oval type, the lateral oval type may be developed in the future because it has the merits of making the longitudinal linear form of the tunnel shallower and reducing the surplus space. However, the segment is quite heavy. Furthermore, development of non-round shield has recently begun.

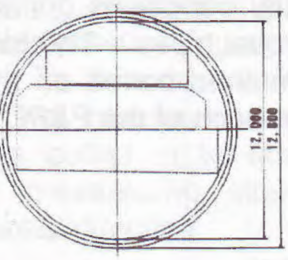

Figure 8 : Round Type (Case 1)

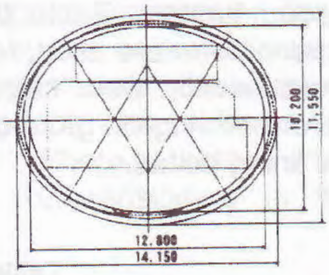

Figure 9 : Lateral Oval Type (Case 2)

6. CONCLUSIONS

Because the P&PCSL uses prestress, it is more suitable for tunnels with medium to large apertures, which are largely affected by the self weight, tunnels exposed to internal pressure, and tunnels with no inner concrete lining. We can thus expect the segment to be applied more widely in the future. We are intending to further rationalize its workability by accumulating achievement. Sumitomo Construction Co., Ltd., Toa Corporation, JDC CORPORATION, and Sumiken Concrete Industries Ltd jointly developed this technology.